Space Weather Technical Forecast

Issued on Wednesday, 22 December 2021 at 13:29 Local

This technical forecast provides a four day assessment of space weather events. The probabilities stated below are for reaching or exceeding the given levels. For more information about space weather impacts please see the Met Office Space Weather Scales https://www.metoffice.gov.uk/weather/learn-about/space-weather/uk-scales

Space Weather Forecast Headline: Chance of G1/Minor Storm on Day 2 (23rd) due to a forecast CME arrival. Moderate solar activity likely throughout. Slight chance of Active fluence.

Analysis of Space Weather Activity over past 24 hours
Solar Activity: Solar activity has been moderate over the past 24 hours, with numerous C-class flares observed, and one M-class flare at 22/0654UTC from AR2908 in the southeast quadrant. This appears to have produced a CME which will be analysed once further data becomes available to determine if it has an Earth-directed component. A filament eruption from close to AR2912 and ex-2914 at 21/1728UTC produced a CME and an EUV wave, but given the position is unlikely to have produced an Earth-directed CME, although this will also be analysed.

There are 11 sunspot regions on the visible disc, with three significant regions in the southwest quadrant 2907 (Dai/Beta-Gamma), 2908 (Dai/Beta) and 2909 (Dao/Beta) contributing most of the flare risk, with several regions assessed to be relatively stable and therefore present a lower risk. Emerging region 2816 (Cso/Beta) close to the southeast limb, has produced a number of flares on the far side of the Sun and is likely to present a significant flare risk once a detailed analysis is undertaken.

Solar Wind / Geomagnetic Activity: Solar winds speeds as measured by DSCOVR at L1 has been mainly elevated throughout, from a peak of around 600km/s, the speed has averaged 575km/s under the influence of the high speed stream from coronal hole 35. Density has also been stable for much of the period at around 14ppcc. Interplanetary magnetic field strength (IMF), Bt has been weak throughout, with the north-south component, Bz also varying weakly. Phi angle has been predominantly negative (towards the Sun). Geomagnetic activity was Quiet to Unsettled.

Energetic Particles / Solar Radiation: The high energy proton flux (greater than 10 MeV) remained at background levels. The high energy electron flux (greater than 2 MeV) was at mainly background levels, but peaked at 963 pfu at 21/2020UTC. The associated 24-hour integrated fluence remained well below the Active threshold and stable. A fluence of 2.47e7 was observed at 22/0000 UTC.

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Met Office Space Weather Technical Forecast

Four-Day Space Weather Forecast Summary

Solar Activity: Solar activity is forecast to be mainly moderate, due predominantly to three complex sunspot regions in the southwest quadrant and an emerging, but active, region close to the southeast limb. There are also a number of filaments in the southern hemisphere which, while currently stable, continue to be monitored. A CME which left the Sun on 20 December from 2908 is forecast to arrive at Earth on late on 23 December, or early on 24 December.

Solar Wind / Geomagnetic Activity: The CME which left the Sun on 20 December is expected to arrive at Earth on 23 December, or perhaps early on 24 December. Solar wind speeds are expected to remain elevated through day 1 (22 Dec) and much of day 2 (23 Dec), due to the high speed stream from coronal hole 35. A decline towards background levels is then forecast on days 3 and 4. Any decline in speeds is subject to the forecast CME arrival which could briefly elevate winds to around 500km/s. Geomagnetic activity is expected to be mainly Quiet through day 1 and much of days 2 and 3, although Unsettled to Active intervals are possible in any periods of negative Bz. There is a slight chance of Active or G1/Minor Storm intervals on 23 or 24 December due to the 20 December CME. Quiet to Unsettled conditions are then likely on day 4.

Energetic Particles / Solar Radiation: The high energy (greater than 10 MeV) proton flux is expected to remain at background levels and below the S1 level, although there is a very slight chance for some increased flux from any significant flare activity. High energy electron flux has been at mainly moderate levels and may exceed the high threshold on days 1 to 3 on diurnal highs due to the persistently enhanced high speed stream, which is forecast to decline from day 3 onwards. Any increase in flux may also be inhibited by the forecast CME arrival. Electron fluence is forecast to follow an increasing trend, with a slight chance of reaching the Active (1e8 integrated pfu) threshold through the period.

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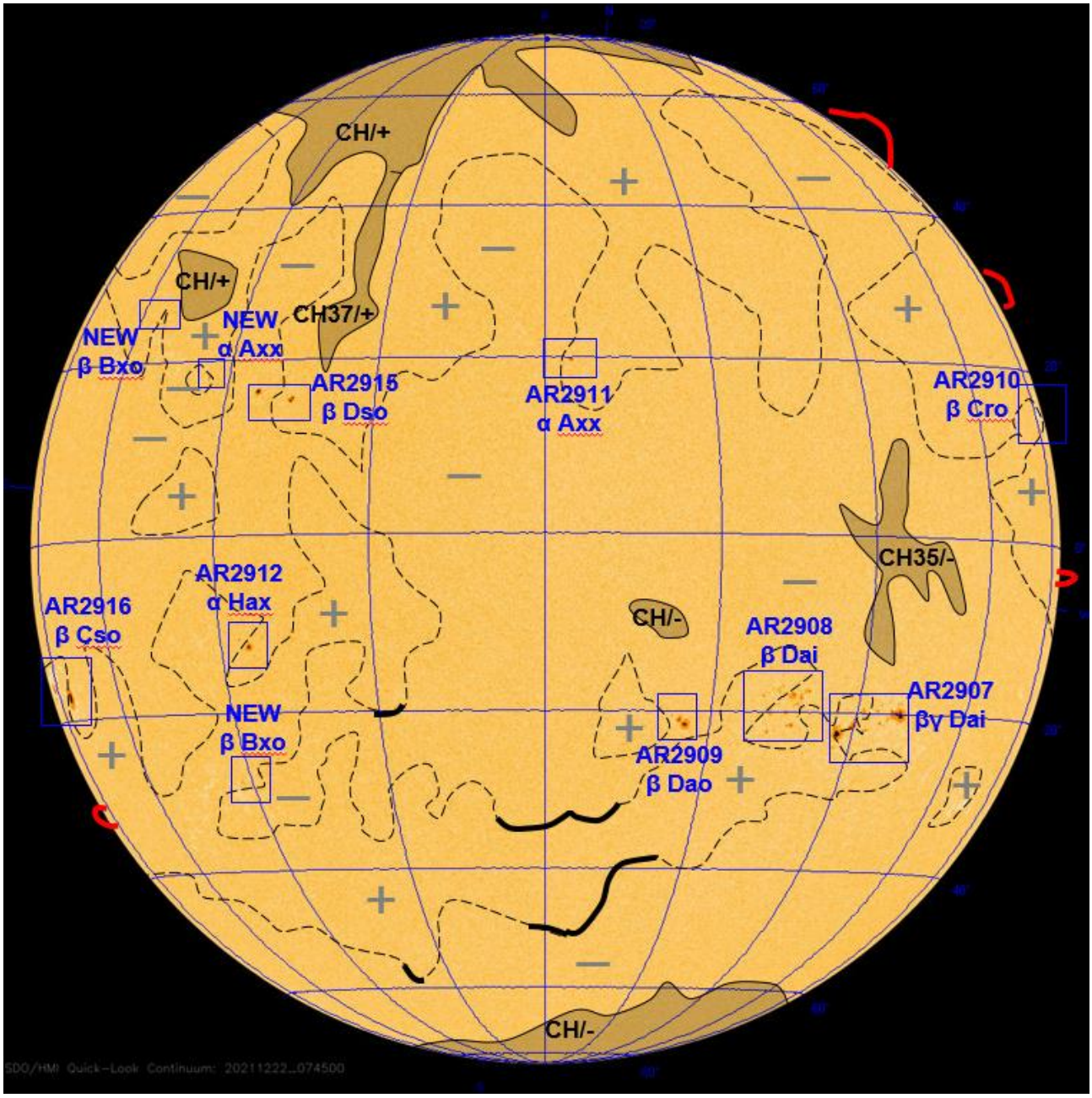
Figure 1. Solar Analysis Valid 22/0800UTC.



Key: Filament ___ , Prominence ___ , Magnetic Field Line - - - , Polarity +/-, Coronal Holes: Grey shaded area CHxx +/-, Sunspot groups 25xx - Mt Wilson α-β-βγ-βγδ and Zurich-McIntosh Axx etc.

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Geomagnetic Storms:

Earth is currently being influenced by the high speed stream from coronal hole 35, which is producing speeds of around 575km/s. This is expected to stay connected to the Earth through the next two days as it rotates towards the western limb, with speeds then waning through days 3 and 4 (24 and 25 Dec).

A CME which left the Sun on 20 December has been analysed and is forecast to arrive at Earth either late on 23 or early on 24 December, with a partial halo forecast. Speeds may be elevated to around 500km/s as a consequence of the CME arrival.

Geomagnetic activity is forecast to be mainly Quiet, with a chance of Unsettled or Active intervals in any sustained periods of negative Bz, in the presence of the elevated high speed stream. There is also a chance of Active and a slight chance of G1/Minor Storm intervals due to the potential CME arrival on 23 or 24 December.

Geo-Magnetic Storm Probability (Exceedance)	Level	Past 24 Hours (Yes/No)	Day 1 (00-24 UTC) (%)	Day 2 (00-24 UTC) (%)	Day 3 (00-24 UTC) (%)	Day 4 (00-24 UTC) (%)
Minor or Moderate	G1 to G2	No	10	30	20	10
Strong	G3	No	1	1	1	1
Severe	G4	No	1	1	1	1
Extreme	G5	No	1	1	1	1

Geomagnetic Activity - Earthbound Coronal Mass Ejections

Date/time 21.5R (UTC)	Halo: Full or Partial	Source	Source Location	Estimated Speed	Estimated Arrival Time	Comments
20/1804UTC	Partial	AR2908	S14 E11	625	23/1200UTC	Limited

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Figure 2: MOSWOC Enlil showing forecast CME arrival from eruption on 20 December.

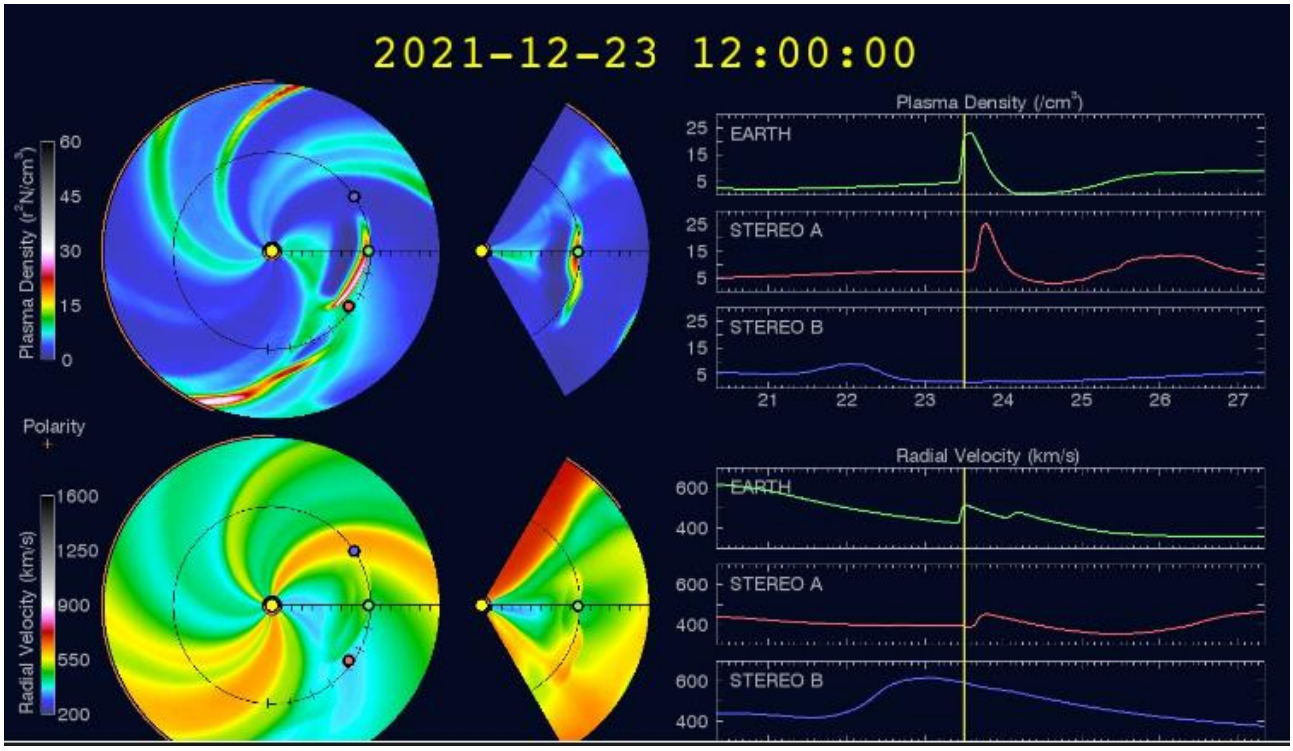
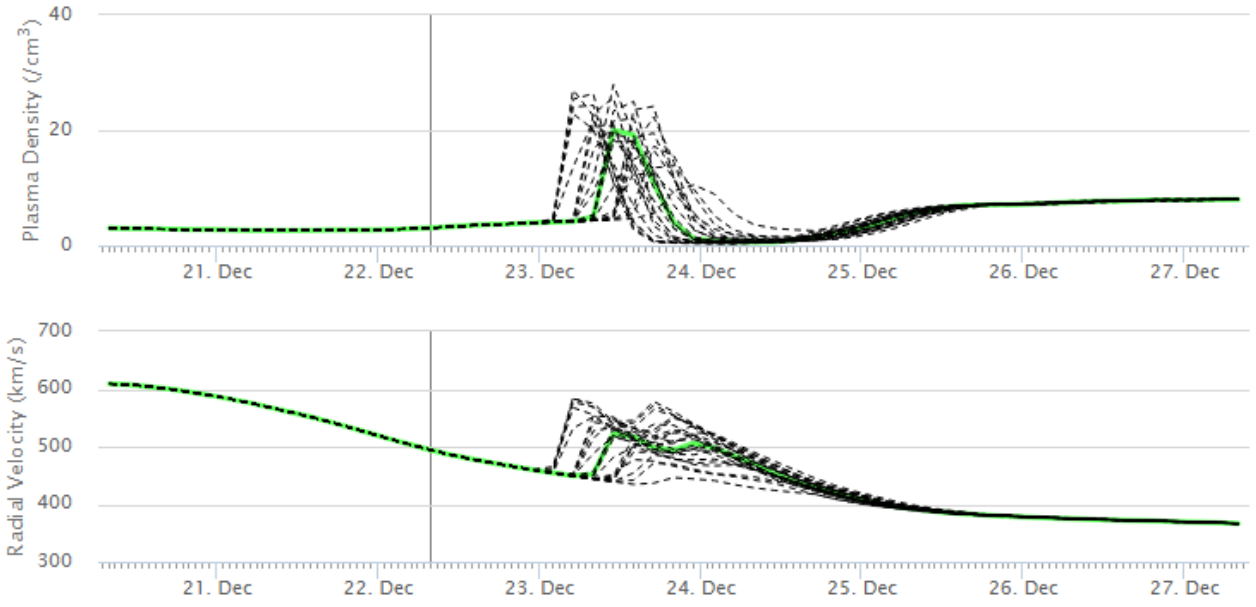


Figure 3: MOSWOC Enlil Ensemble, showing potential range in arrival times for CME, demonstrating the risk of a later arrival on 24 December.



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Radio Blackouts - X-Ray Flares:
There are 11 analysed sunspot regions on the visible disc, with two regions fading and three weak regions appearing during the last 12 hours. Moderate activity is expected to continue through the next 4 days, with the majority of the flare risk due to the regions in the southwest quadrant and the emerging region close to the southeast limb.

The three significant regions in the southwest quadrant but each with varying trends in development. 2907 (Dai/Beta-Gamma) has a high flare risk, but has appeared to be relatively stable through the last 24 hours with a slight spreading of the intermediate spots. 2908 (Dai/Beta) has produced a recent M-class flare but has subsequently shown a reduction in the number of distinct spots. 2909 (Dao/Beta), while relatively stable has started to develop some trailer spots and is now classified as a Beta region.

2916 (Cso/Beta) is also rotating across the southeastern limb, and although the configuration currently appears relatively simple, foreshortening makes any detailed analysis difficult. it is expected that this region, which has also produced an M-class flare in the last 24 hours, will prove to be a complex active region.

The remaining sunspot regions all appear to be benign, but will be monitored for further development.

X Ray Flares	Level	Past 24 Hours (Yes/No)	Day 1 (00-24 UTC)	Day 2 (00-24 UTC)	Day 3 (00-24 UTC)	Day 4 (00-24 UTC)
Probability			(%)	(%)	(%)	(%)
Active	R1-R2 M Class	Yes	40	40	40	40
Very Active	R3 to R5 X Class	No	2	2	2	2

Figure 4: GOES-16 24 hour X-ray flux

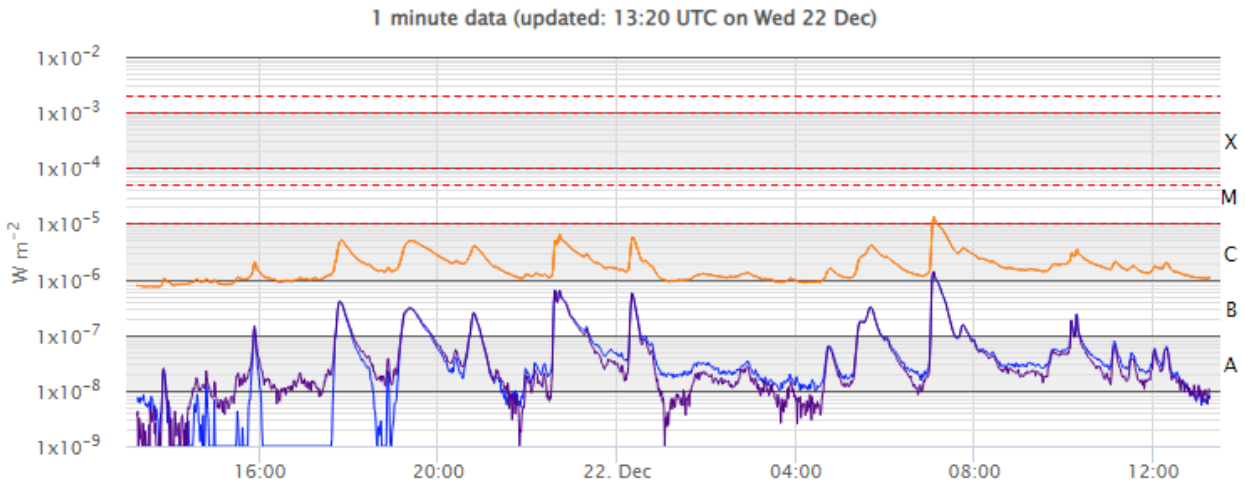

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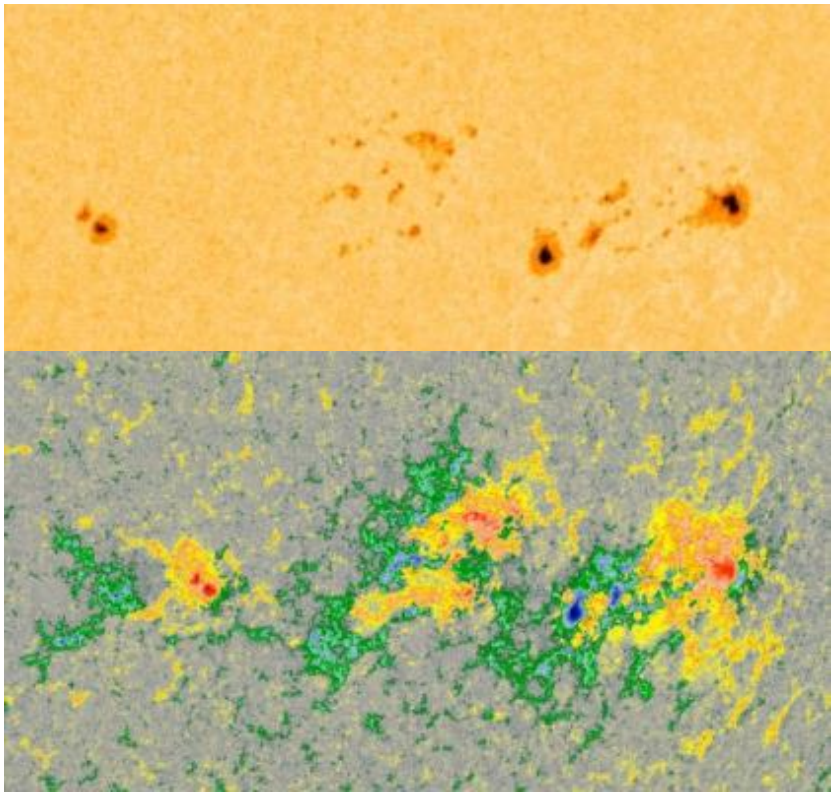
Figure 5: HMI SDO intensitygram and magnetogram imagery for the region (from left to right) 2909, 2908, 2907. The middle region produced a M1.3 flare at 22/0654UTC.



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Solar Radiation Storms - (High Energy Protons):
The high energy proton flux (greater than 10 MeV) as observed by GOES-16 is currently at Background levels.

Despite the large number of sunspots on the disc, a number of which are now moving into an improved geoeffective location for radiation storms, their small size and generally simple magnetic structure means that proton rich flaring is unlikely.

Background levels are expected to persist, with a chance of some small increases from any notable flares that do occur. However, there is only a very slightly above background risk of rising to the S1 alert level.

Radiation Storms Probability (Exceedance)	Level (cm^{-2} sr^{-1} s^{-1})	Past 24 Hours (Yes/No)	Day 1 (00-24 UTC) (%)	Day 2 (00-24 UTC) (%)	Day 3 (00-24 UTC) (%)	Day 4 (00-24 UTC) (%)
Active	**≥ S1**	No	5	5	5	5
Very Active	**≥ S3 ***	No	1	1	1	1
* S3 ≥ 10 MeV ≥ 1000 pfu and / or ≥ 50 MeV ≥ 10 pfu. (pfu = $cm^{-2}sr^{-1}s^{-1}$)						

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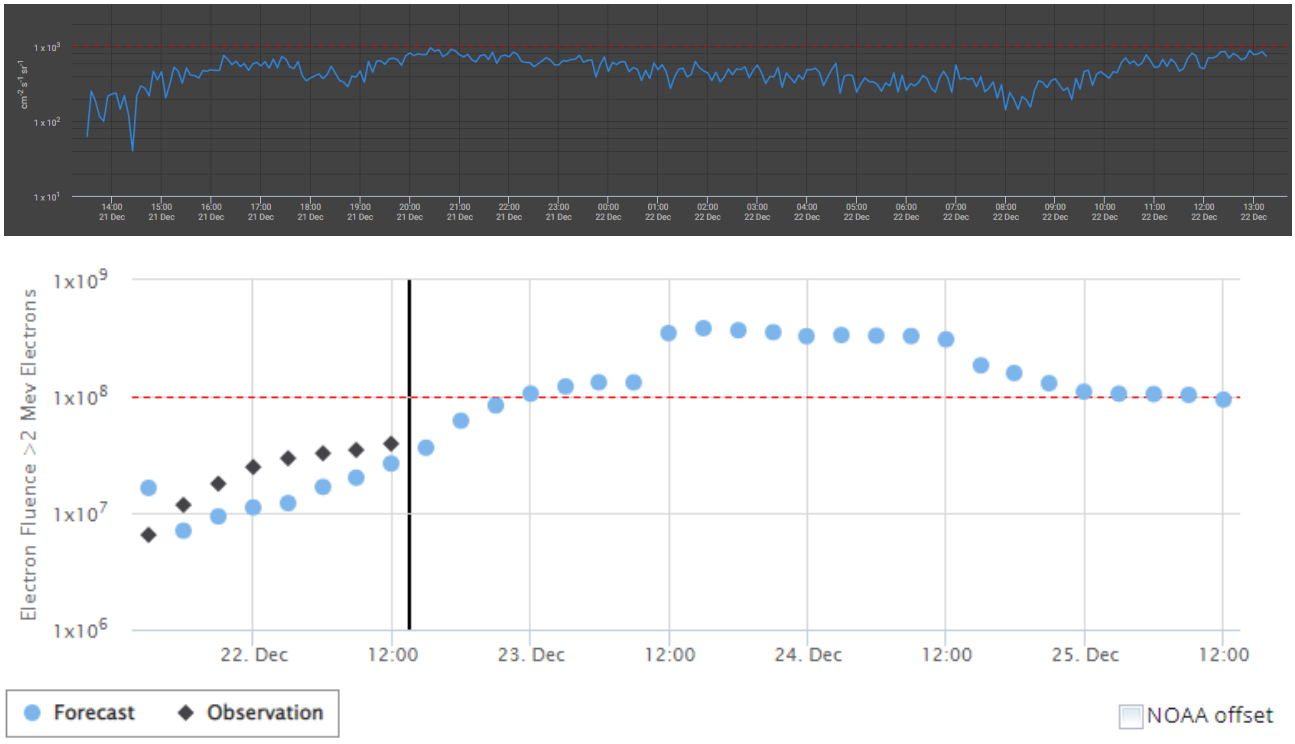
High Energy Electrons Event (≥ 2MeV):
The high energy electron flux (greater than 2MeV) at GEO has been close to the high (1e3pfu) threshold and is expected to continue at this level, with a chance of exceeding the threshold during days 1 to 3 on diurnal maximum due to a consistently elevated high speed stream, with this then expected to start waning through day 3. There is a CME forecast to arrive either late on 23 December or early on 24 December which is likely to enhance geomagnetic activity and result in a redistribution of electrons within the radiation belts.

Electron fluence values are showing a slight levelling off after a previous steady but sustained increase. The anticipated CME effects are likely to hinder any significant increase from day 2 onwards, despite the elevated high speed stream, with only a slight chance of exceeding the Active (1e8 integrated pfu) threshold through the period.

GEO Electron Environment	Level (cm^{-2} sr^{-1} day^{-1})	Past 24 Hours (Yes/No)	Day 1 (00-24 UTC)	Day 2 (00-24 UTC)	Day 3 (00-24 UTC)	Day 4 (00-24 UTC)
Probability (Exceedance)			(%)	(%)	(%)	(%)
Active	≥ 2 MeV ≥ $1x10^8$	No	30	30	30	20
Very Active	≥ 2 MeV ≥ $1x10^9$	No	1	1	1	1

Figure 6: GOES 16 electron flux (top) and MOSWOC REFM model (bottom)



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